

EVOLUTION OF CARBONACEOUS CHONDRITE PARENT BODIES: INSIGHTS INTO COMETARY NUCLEI? Harry Y. McSween, Jr., Department of Geological Sciences, University of Tennessee, Knoxville, TN 37996-1410.

Much of the excitement about obtaining cometary samples accrues from the conventional view that they will comprise the most primitive materials that we can get our hands on. Although "parent body" alteration of such samples would not necessarily detract from this interest, we should keep in mind the possibility that modification processes may have affected cometary nuclei. Inferences about the kinds of modifications that might be encountered can be drawn from data on the evolution of carbonaceous chondrite parent bodies. The following observations suggest that, of all the classes of chondrites, these meteorites are most applicable to the study of comets: (a) Carbonaceous chondrites are chemically the most primitive meteorites. The elemental abundances of CI chondrites provide the closest match with the composition of the solar photosphere; (b) Spectral reflectivity surveys of asteroids suggest that carbonaceous chondrite-like bodies reside primarily in the outer asteroid belt. Their formation locations thus lie closer to inferred comet accretion sites [1]; (c) Petrographic studies of carbonaceous chondrites indicate that they formed in volatile-rich environments, and H₂O and other volatiles may have been incorporated initially as ices [2]; (d) Some types of chondritic interplanetary dust particles (IDPs), which may be solid debris from short period comets, are mineralogically similar to carbonaceous chondrites [3]. Moreover, both of these materials appear to be broadly similar in composition to Comet Halley dust [4].

Most carbonaceous chondrites show evidence of parent body heating, commonly in the form of aqueous alteration. Although aqueous alteration clearly took place at low temperatures [5], heat was necessary to produce water from ice. Decay of short-lived radionuclides like ²⁶Al is one plausible heating mechanism for asteroids that could presumably affect comets as well. External heat sources such as electromagnetic induction by a massive solar wind have also been suggested for asteroids, but the decrease in effectiveness of this mechanism with solar distance renders this heat source unlikely for cometary bodies. An additional heat source for comets could be provided by close passage near the sun, or near passing stars in the Oort cloud.

Melting of ice in carbonaceous chondrite parent bodies resulted in profound mineralogical changes. The original (presumed anhydrous) chondrite assemblage has been altered to intimate mixtures of fine-grained phyllosilicate minerals like serpentine, smectite, chlorite, as well as poorly crystallized oxides, hydroxides, and other complex phases [3,6]. It is generally believed that chemical changes accompanying aqueous alteration were minor, although this conclusion is based primarily on similarities to solar elemental abundances which are not precisely measured. The strongest reported enrichments of the heavy isotopes of O, N, and C occur in chondrites which have been exposed to aqueous alteration [7]. Thermal models for ice-bearing planetesimals [8] indicate that ice acts as a thermal buffer, accounting for the difference in metamorphic history between parent bodies for ordinary and carbonaceous chondrites.

Virtually all classes of meteorites show the effects of impact processes, and it seems possible that cometary materials may have experienced impacts before or possibly after accretion. Shock metamorphic effects include partial destruction of the crystal structures of many minerals, recognizable from their optical and X-ray diffraction properties.

Uniaxial compaction and deformation of chondrules in a few carbonaceous chondrites have also been recognized [9]. Most, if not all, carbonaceous chondrites are breccias, containing clasts with variable alteration histories. Shock can also cause dehydration of phyllosilicates [10], although evidence for this process has not been recognized in carbonaceous chondrites.

Many chondrites have been irradiated by solar wind, solar flare, and cosmic ray particles. The penetration depths for these particles vary with their energies, but none can penetrate appreciable depths. For this reason, most chondrite irradiation occurred in regoliths on parent body surfaces or during exposure as small meteoroids in space. A high proportion of carbonaceous chondrites contain solar-wind implanted noble gases, as well as significant amounts of cosmogenic nuclides and solar flare tracks in mineral grains [11].

How applicable, if at all, are these processes to comets? If the proportion of possible internal heat sources such as ^{26}Al in cometary materials are similar to those in chondrites, and if the time scale of comet accretion was fast enough to permit incorporation of "live" radionuclides, comets might have had early thermal histories somewhat like those of carbonaceous chondrite parent bodies. We might then predict that cometary dust should contain some phyllosilicate minerals and other phases formed by aqueous alteration. At least some chondritic IDPs contain phyllosilicates. However, similarities between the chemical compositions of anhydrous IDPs and Comet Halley dust [4] may suggest that aqueous alteration processes have not appreciably affected this cometary nucleus. Impact processes possibly affected cometary materials during their initial accretion, and possibly during ejection from the outer solar system into the Oort cloud. We should be prepared to find that comets are heterogeneous, consisting of rock fractions with different thermal and shock histories. In fact, the comet nucleus itself may ultimately be viewed as a megabreccia, comprised of rock and ice blocks and clasts. The shielding characteristics of ice are similar to that of rock, and along with the unlikelihood of comet regoliths, this might suggest that irradiation of cometary materials is unlikely. However, conceptions of comet surfaces that envision dusty mantles or icy pedestals capped by dust certainly offer opportunities for sample irradiation, and cosmic ray tracks have been observed in chondritic IDPs.

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